Geothermal energy from mines water
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The speaker's research background has been in fluid dynamics, heat transfer and fluid flow. The mines water interest had been triggered some years ago by a talk from Alison Monahan at BGS, describing how a mine water heating study had been undertaken in Glasgow, and assisted greatly by a mine expert at Durham called Charlotte Adams, and the Durham Energy Institute which hosts people with an interest in any form of renewable energy and with a range of specific interests, from drilling to heat storage, finances, regulations and the social aspects associated with utilising mine water. After drafting a research proposal, Durham now has a team looking at the whole topic of mine water heating.

The average geothermal gradient in the UK is about 25C per km depth, and about 23,000 mines (mostly coal) in the country, typically at a few hundred metres depth. They are mostly flooded but the water is warm, around 12 to 20C or sometimes 25C, and about a quarter of UK homes actually sit above old coal mines. Consequently, if heat could be extracted from these mines it would clearly be a low carbon source. To do this, several open loop systems would need to operate, that is two boreholes into the mine workings for each loop, where warm water is pumped through a heat pump which extracts about 5-8C from the mine water via another water circuit and heated up to about 40C. The housing loop is isolated from the mine water circuit. The cold water remaining is pumped down the second borehole and returned to the mine system, working its way slowly from the injection point back to the extraction point, warming as it goes.

If the system is used carefully, this resource can be used indefinitely without any environmental pollution. Clearly if there is too much abstraction, the mine water system will cool at a greater rate than the natural geothermal balance and the system will cease. This is known as thermal breakdown and to help understand this, computer simulations have been created to determine what would be the optimal places to drill the boreholes and how much water can be extracted. In fact, this is not new, similar systems were set up on a small scale in Canada and the US in the 1980s, by small companies or small communities. In the Netherlands, one of the first to be established was in the town of Heerenveen, where it was decided to use heat from AC systems and commercial-industrial waste heat back into the Earth during the summer, to develop a geo-battery. Further work is required to establish how many boreholes are required, what is the drilling risk and targeting accuracy is, and the finance and licencing regulations required to operate mine water systems long term. This is a developing technology and nowhere near as well established as wind power or PV cells. In addition, there are some challenges from the social aspects of district heating such as collaboration with the local community, retrofitting of houses, replacement of gas boilers, providing underfloor heating and better insulation etc, all of which does provide an excellent opportunity for 'levelling up' as many ex-mining communities sit right on top of the old coal mines, potentially with new employment opportunities and social enhancement.

Q. What is the scale of separation between injection and extraction boreholes?
A. Probably kilometres, but it depends on the nature of the original mine system.

Q. Have you been successful in getting the porosity models from the older and more modern mine systems to work together?
A. This is indeed a challenge. Initially the team started working with a stope and pillar mine system up to several km wide, with underground corridors as narrow as a few metres, requiring enormous resolution. This was modelled using a 'pipe' network, where each roadway underground was treated as a pipe. Other models have been used with backfilled roadways, using the concept of a porous

media pipe model, and a model for a mine with a total collapsed extraction history. This is one of the key aims of the current research, to get realistic models created.

Q. How would the levelling up process work?
A. Old mining communities would likely get the highest benefit for low-cost heating due to their mainly dense housing in a small deprived area, especially given that it is not feasible to take the heat extracted from the mine system very far.

Q. Did the Waste Institute contribute to Govt. consultations?
A. Yes, and mines water was included in the Govt's 10-point geothermal plan and BAIS expressed strong interest.

Q. Are we dealing with shallow or deep mines, since the water distribution would be expected to be very different, and secondly who owns the old mines?
A. From new projects that have been developed near Gateshead, shallow mines have been used, but the abstraction boreholes have been at different levels from the injection boreholes. Many pumping tests were conducted to determine whether the circulation system was relatively open or quite restricted, and how water levels and pressures changed. In the more open systems near the coast, it was even possible to detect tidal pressure fluctuations! Deeper mines will likely be much more isolated from ground water changes. The land owner does not own the water, but the Coal Authority does control who has access to which mine system, and access to the mine itself for drilling of course with the Environment Agency controlling water quality at the surface. Ultimately of course, it is not ownership of the water that it really the point, it is who 'owns' the energy from it.

Q. How do you certify a ground water system and package it for an investor?
A. In the 1930s the underground resource for hydrocarbons was nationalised, which contrasts with the US where land owners have proprietary rights over ground fluids (the Petroleum Production Act). For the UK, it is very likely that the petroleum business would be likely to be the model for licensing of fluid resources.

Q. Do coalfield shales not inhibit water circulation?
A. In old workings, there are frequent fractures from the impact of mining on the ground system and so the entire system can often be regarded as a permeable entity.

Q. What sort of drilling problems have you encountered?
A. Drilling undoubtedly represents the biggest single risk factor and the failures are inevitably expensive. It is very common to drill several boreholes before one is successful, perhaps due to drilling into a pillar, or into rubble, losing circulation, clogging up the system, or lack of control of the drilling direction. Near Newcastle, a mine systems outcrops on the beach, so one aspect of the research has been to examine how the fracture system changes as you move away from the workings.

Q. How have these studies affected the initial modelling?
A. One of the key aims at the outset was to have a means of calibrating the models against the real world, and but it turns out there have been very few systems that have provided useful data to compare with models. In other words, while a mine system can be demonstrated to have a stable temperature regime, which is ideal, knowing how to predict if or when it would cool down is not known.

Q. Is there some way to modify the ground system by grouting for example?
A. Grout walls can be provided near the borehole itself, mine workings have even been blocked off completely in the Midlands, and old ventilation systems can be opened or closed at will.

Q. Would it be possible for a new shaft to be drilled to drain the whole of a mine and adapt it to make a more efficient geothermal system?
A. In concept, yes, but creating a completely new 3D flow system would be unacceptably expensive. However, there is a great deal that can be achieved from boreholes alone to inform the mining issues, including using fibre optic cameras, 3D surveying etc, not restricted to coal mines, especially where there are accurate 3D plans (e.g. South Crofty mine).

Q. Have there been any examples where the water quality has had major implications for the system itself?
A. Mine water often contains a lot of iron and/or sulfur, but if there is any contact with oxygen, iron will precipitate as ochre scaling which can block pipes, and so early systems have had to be closed down for this reason. Modern systems therefore mitigate against oxygen entry. Also, sulfidic waters from both coal and associated mudstones are highly acidic and corrosive on heat pump systems.

Q. Has the research area been extended outside of the Durham area?
A. There are systems being drilled in the Gateshead and Sunderland area but the Greater Manchester region and S Wales are also possibilities. However, much of the research is generic so it can probably deliver results applicable elsewhere. Discussions are also taking place with Exeter Uni with respect to Cornish mines, where knowledge of the geometry is key for understanding extended mine systems.

Q. Do modern geology and geophysics courses provide the skills required?
A. We probably need more hydrogeology, engineering, geochemistry and even anthropology or sociology which are important aspects for this research, but it will depend highly on what course modules have been chosen. For example, renewable energy modules.

John Bennett